N90-22660

Program 8 **Quantitative Characterization of Spatial Distribution of Particles in Materials: Application to Materials Processing**

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Project Objective

The objective of this project is to develop methods for quantitative analysis of the spatial distribution of second phases in structural materials. Coupling of these methods with models and/or experimental data for deformation and fracture will reveal the effects of non-random phase distribution on material performance.

A Method for Analyzing the Uniformity of Distribution of Second Phase Particles

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Abstract

Most engineering materials contain second phase particles or fibers which serve to reinforce the matrix phase. The effect of reinforcements on material properties is usually analyzed in terms of the average volume fraction and spacing of reinforcements, quantities which are global microstructural characteristics. However, material properties can also depend on local microstructural characteristics; for example, on how uniformly the reinforcing phase is distributed in the material. Previous studies have shown that the ductility and fracture properties of particulate composite materials depend on the distribution of particulate in the matrix. Similarly, electrical conductivity in metal-filled polymers depends on the uniformity of distribution of metal fibers. Only a few attempts have been made to analyze the distribution of particles in engineering materials. The objective of this research project is to develop a method for analyzing clustering of second phase particles in a matrix. The analysis method will then be applied to a materials processing problem to discover how processing parameters can be selected to maximize redistribution of the reinforcing phase during processing.

Several mathematical analysis methods could be adapted to the problem of characterizing the distribution of particles in materials. A tessellation-based method has been selected for the present investigation. In the first phase of the investigation, a software package has been written to automate the analysis. Typical results will be shown during the presentation. The analysis technique allows us to find the degree to which particles are clustered together, the size and spacing of particle clusters, and the particle density in clusters. The analysis methods have been applied to computer-generated distributions and to a few real particle-containing materials.

Methods for analyzing a nonuniform particle distribution in a material can be applied to two broad classes of materials science problems: understanding how processing methods affect the particle distribution and understanding how the resulting particle distribution affects properties. Previous investigators have analyzed how a nonuniform particle distribution affects fracture of a MMC. We have chosen to apply the analysis method described above to a materials processing problem: how to select extrusion conditions to maximize the redistribution of reinforcing particles that are initially nonuniformly distributed. The experiments will be conducted using a model material, but the results will be applicable to extruded MMCs, powder-metallurgy materials and filled polymer composites. In addition, interaction with a student in the Department of Applied Mathematics has led to adaptation of our tessellation-based method to analyze star distributions in spiral galaxies, illustrating the diverse types of problems to which the analysis method can be applied.

A METHOD FOR ANALYZING THE UNIFORMITY OF DISTRIBUTION OF SECOND PHASE PARTICLES

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OUTLINE

- INTRODUCTION
- METHOD OF ANALYSIS
- DIRECTION OF RESEARCH
- SUMMARY

OBJECTIVE

TO DEVELOP A METHOD FOR ANALYZING THE UNIFORMITY OF DISTRIBUTION OF SECOND PHASE PARTICLES

INTRODUCTION

- Most engineering materials are composed of two or more phases

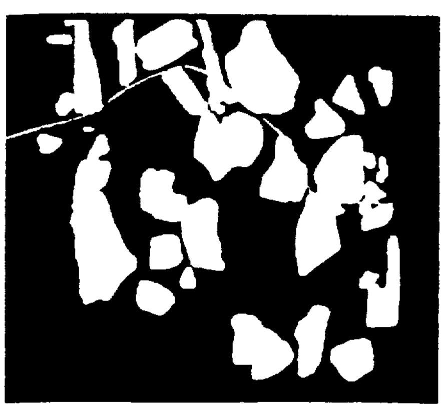
- Many properties of interest to the researcher, manufacturer, or designer depend on the distribution of the second phase:

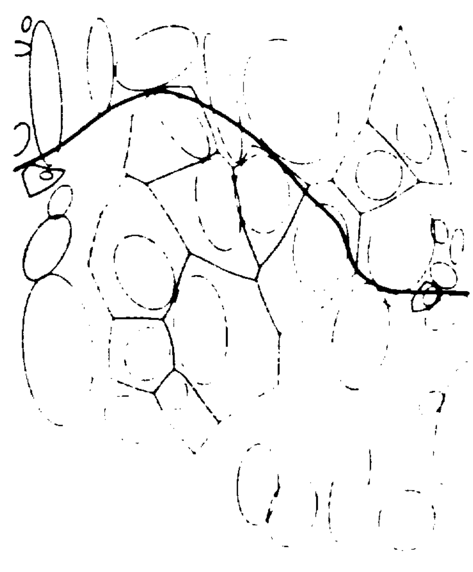
  Fracture Characteristics
  Strength
  Stiffness
  Electrical/Thermal Conductivity

EXAMPLE 1

- Fracture characteristics of particulate reinforced metal matrix composites (MMC's).

- Crack path typically follows regions of high local reinforcement volume fraction; leads to lower energy absorption.



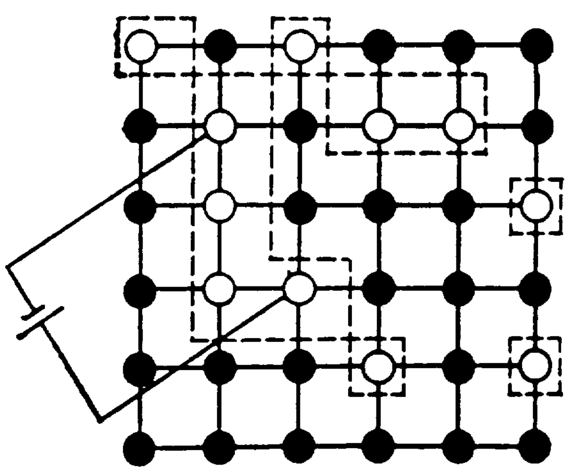


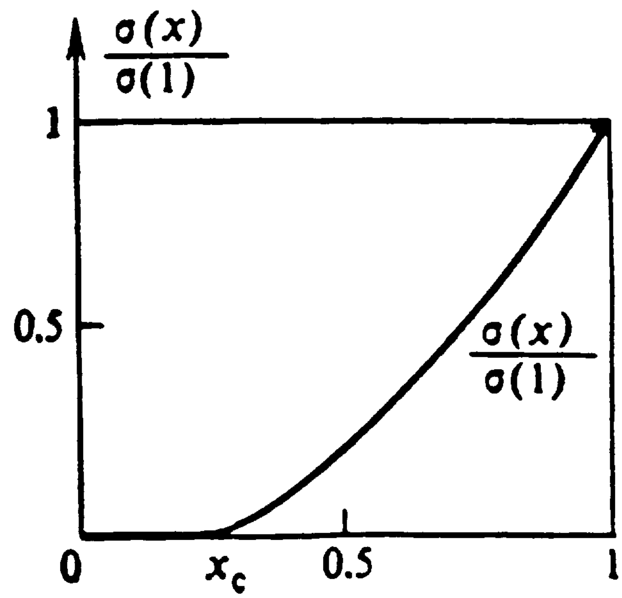
Liu, Lewandowski and Hunt (1989)

EXAMPLE 2

- Electrical conduction in metal filled polymers

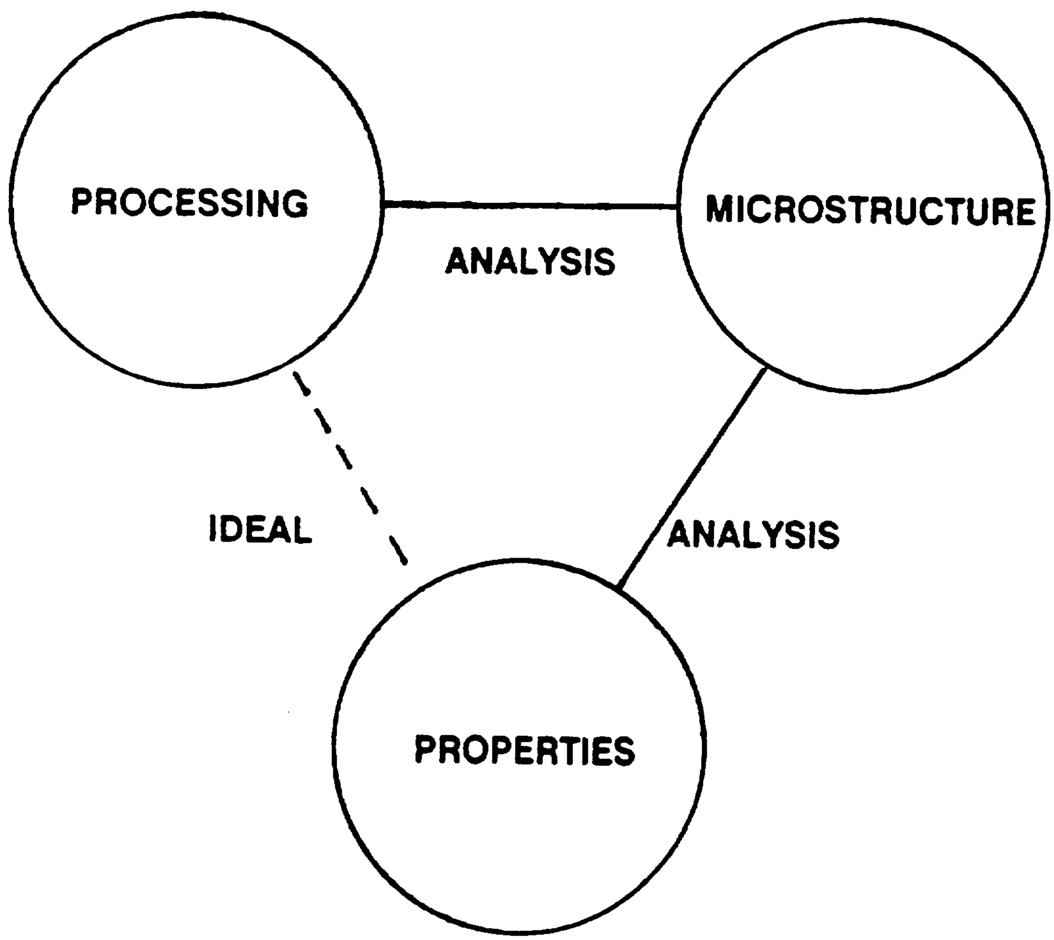
- Electrical conduction depends on distribution and volume fraction of second phase.





Efros (1986)

OPPORTUNITIES FOR APPLICATION OF ANALYSIS TECHNIQUES



PREVIOUS APPLICATIONS TO MATERIALS SCIENCE

Fracture of Two Phase Materials

Embury / McMaster University

- Considered effect of spatial distribution of second phase particles on damage accumulation and fracture initiation in several materials

- Used Dirichlet tessellation technique to quantify spatial distribution and clustering of particles

Liu / ALCOA Laboratories

- Studied crack growth in SiC particulate reinforced 7XXX series Al alloys (PM process)

- Found that crack path tended to follow clustered regions

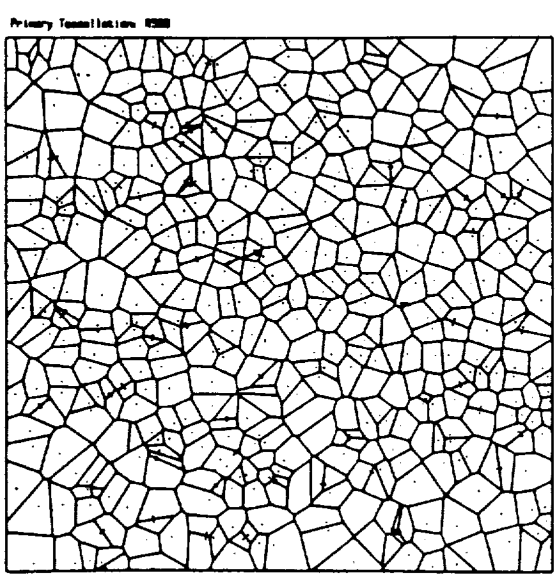
- Clusters were preferred sites for damage initiation and for damage accumulation ahead of the propagating crack

POTENTIAL ANALYSIS METHODS

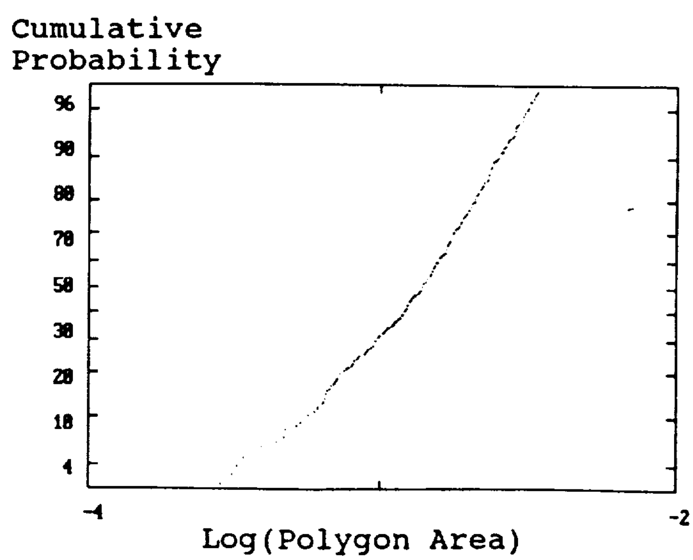
- Tessellation Methods
- Cluster Analysis Methods
- Fractal Dimension Analysis
- Percolation Theory

Basic idea of tessellation analsysis:

Construct tessellation



Analyze characteristics



METHOD OF ANALYSIS

(IN PLACE)

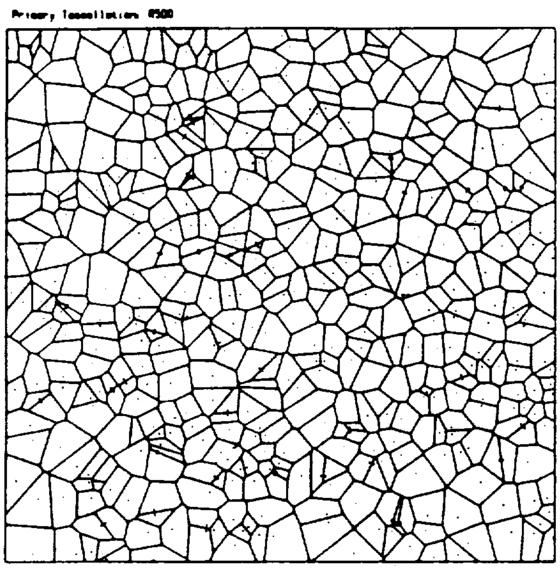
TESSELLATION-BASED ANALYSIS:

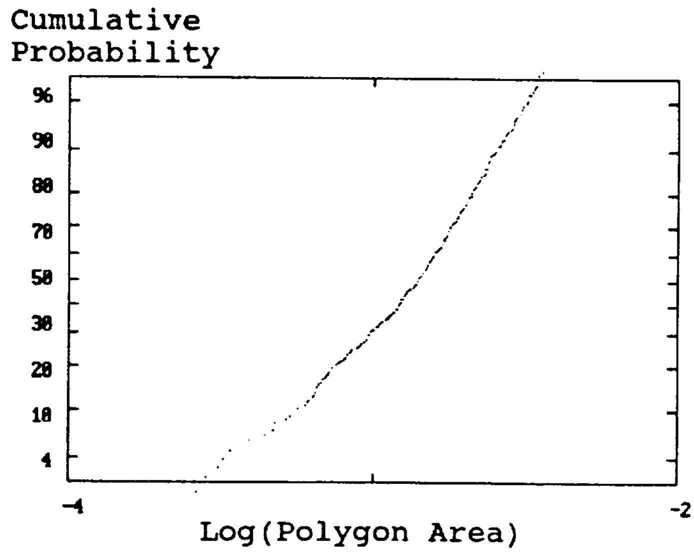
- Properties of individual particles are evaluated
- Yields statistical distribution of parameters for second phase particle distribution
- Currently runs on PC

PARTICLE CLUSTERING ANALYSIS:

- Builds on output of Tessellation Analysis
- Requires working definition of a "cluster"
- Yields properties of groups of particles

TESSELLATION-BASED ANALYSIS





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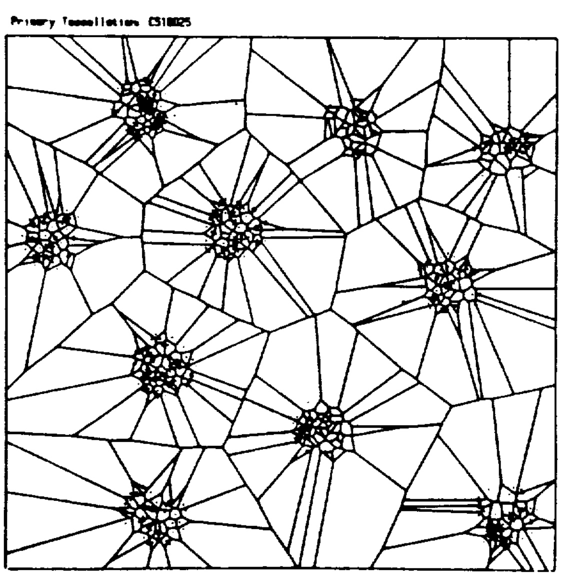

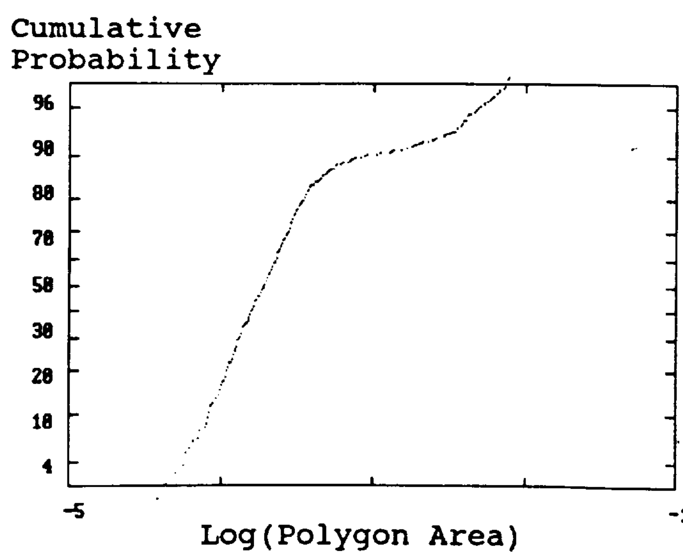

-------------------------CLUSTERED ARRAY-----------------------

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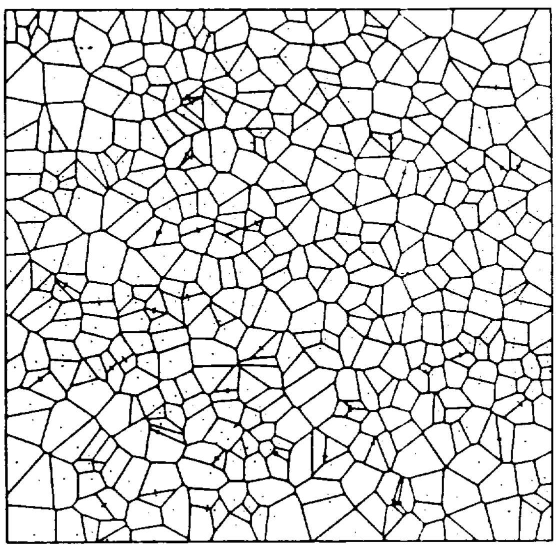
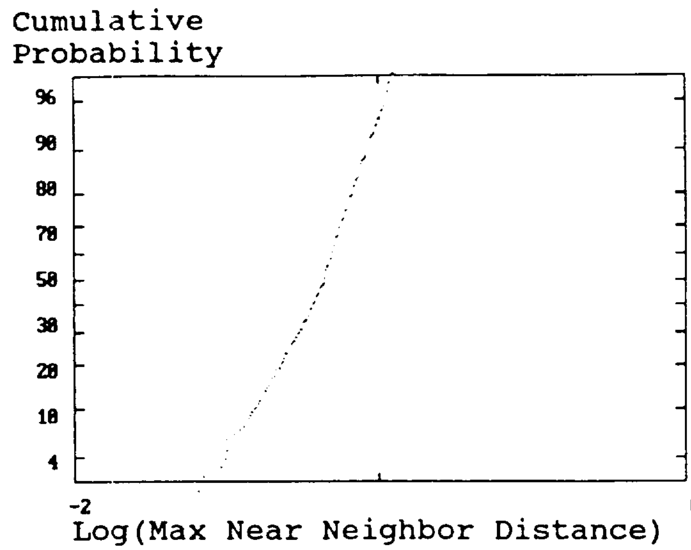
OF POOR QUALITY

PARTICLE CLUSTERING ANALYSIS





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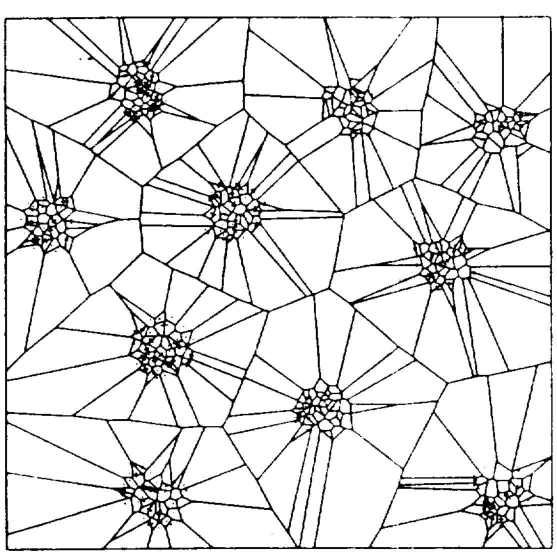

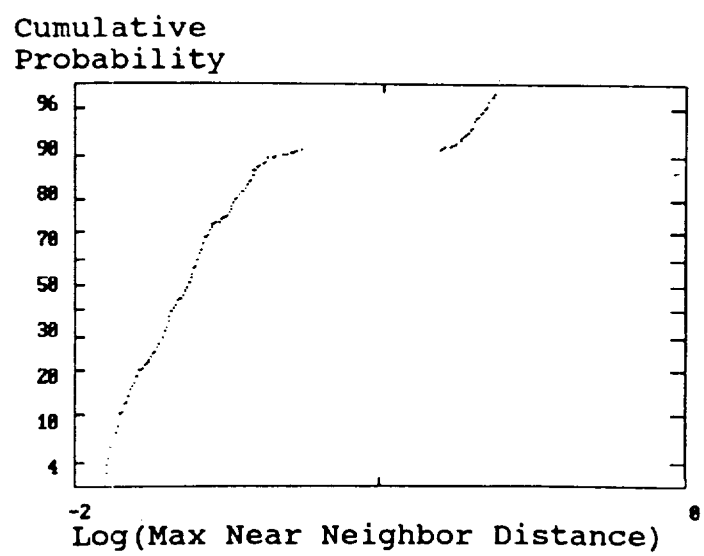

------------------------CLUSTERED ARRAY------------------------

DIRECTION OF RESEARCH:

NEAR TERM GOALS:

Apply analysis techniques to processing of advanced materials:

- Examine the effect of extrusion ratio and die angle on second phase particle distribution in MMC's
- Select a model material for extrusion experiments: hard particles in Pb (fcc) matrix
- Correlate processing parameters with second phase particle distribution

LONG TERM GOALS:

Apply analysis techniques to micromechanical modeling:

- Collaborate with researchers using numerical techniques to model behavior of multi-phase materials
- Incorporate more accurate descriptions of second phase particle distributions into models to allow more realistic representation of real materials

SUMMARY

ANALYTICAL PROCEDURES IN PLACE

- Tessellation analysis gives distribution of properties for individual particles
- Clustering analysis characterizes clustering of particles
- System runs on a desktop PC.

APPLICATION OF ANALYSIS PROCEDURES TO PROCESSING OF REAL MATERIALS

- Analysis of effect of extrusion parameters on the distribution of particles is beginning